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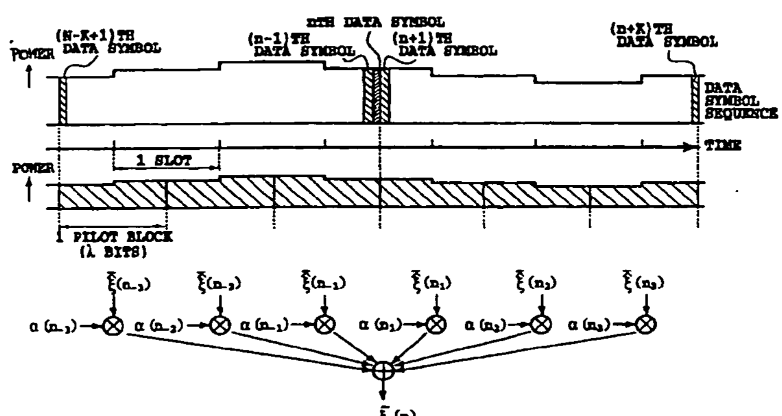
(54) CHANNEL ESTIMATING APPARATUS, AND CDMA RECEIVER AND CDMA TRANSCEIVER EACH HAVING THE APPARATUS

(57) There are provided a channel estimation unit for achieving highly accurate channel estimation, a CDMA receiver and a CDMA transceiver with the channel estimation unit. Channel estimates of data symbols are obtained from a pilot symbol sequence which is parallel with a data symbol sequence. First, a plurality of pilot blocks are generated from the pilot symbol sequence. The channel estimates of the data symbols are obtained by calculating a sum of appropriately weighted averages of pilot symbols in the individual pilot blocks. This enables highly accurate channel estimation. More accurate channel estimation can be achieved by carrying out the channel estimation of the data symbols using the pilot symbols belonging to other slots rather than limiting to the pilot symbols in the slot to which the estimated data symbol belongs.



CHANNEL ESTIMATE OF nTH DATA SYMBOL

FIG.3

EP 0 955 741 A1

[0013] The highly accurate channel estimation and compensation for channel fluctuations in the data symbols based on the channel estimation make it possible for the absolute coherent detection to decide the absolute phase of each data symbol even in the Rayleigh fading environment, which can reduce the SNIR for achieving desired receiving quality (receiving error rate). This can reduce the transmission power, and increase the capacity of a system in terms of the number of simultaneous subscribers.

[0014] In order to accomplish the object aforementioned, according to the invention as claimed in claim 1, a channel estimation unit for obtaining channel estimates of data symbols from a pilot symbol sequence which is parallel to a data symbol sequence comprises:

means for generating a plurality of pilot blocks from the pilot symbol sequence; and
means for obtaining the channel estimates of the data symbols by calculating a weighted sum of averages of the pilot symbols in the individual pilot blocks.

[0015] According to the invention as claimed in claim 2, a CDMA receiver which receives a data symbol sequence that is spread, and a pilot symbol sequence that is spread and parallel to the data symbol sequence, and which generates a data sequence by demodulating the spread data symbol sequence by using the spread pilot symbol sequence comprises:

means for receiving the spread data symbol sequence and the spread pilot symbol sequence;
means for generating a data symbol sequence by despreading the spread data symbol sequence;
means for generating a pilot symbol sequence by despreading the spread pilot symbol sequence;
means for generating from the pilot symbol sequence a plurality of pilot blocks;
means for obtaining channel estimates of the data symbols by calculating a weighted sum of averages of the pilot symbols in the individual pilot blocks;
means for compensating for channel fluctuations in the data symbol sequence by using the channel estimates of the data symbols; and
means for generating the data sequence by demodulating the data symbol sequence compensated for.

[0016] According to the invention as claimed in claim 3, in the CDMA receiver as claimed in claim 2, the spread data symbol sequence has been spread using a first spreading code, the spread pilot symbol sequence has been spread using a second spreading code, the means for generating the data symbol sequence despreads the spread data symbol sequence which has been spread using the first spreading code, and the means for generating the pilot symbol sequence despreads the spread pilot symbol sequence which has been spread using the second spreading code, and wherein the first spreading code and the second spreading code are orthogonal to each other.

[0017] According to the invention as claimed in claim 4, a CDMA transceiver have a transmitting processor and a receiving processor, the transmitting processor generate a spread data symbol sequence by modulating a data sequence, and transmits the spread data symbol sequence with a spread pilot symbol sequence which is spread in parallel with the data symbol sequence, and the receiving processor receives the spread data symbol sequence and the spread pilot symbol sequence, and generate the data sequence by demodulating the spread data symbol sequence by using the spread pilot symbol sequence, wherein
the transmitting processor comprises:

means for generating the data symbol sequence by modulating the data sequence;
means for generating the spread data symbol sequence by spreading the data symbol sequence;
means for generating the spread pilot symbol sequence by spreading the pilot symbol sequence; and
means for transmitting the spread data symbol sequence and the spread pilot symbol sequence, and wherein the receiving processor comprises:
means for receiving the spread data symbol sequence and the spread pilot symbol sequence;
means for generating the data symbol sequence by despreading the spread data symbol sequence;
means for generating the pilot symbol sequence by despreading the spread pilot symbol sequence;
means for generating from the pilot symbol sequence a plurality of pilot blocks;
means for obtaining channel estimates of the data symbols by calculating a weighted sum of averages of the pilot symbols in the individual pilot blocks;
means for compensating for channel fluctuations in the data symbol sequence by using the channel estimates of the data symbols; and
means for generating the data sequence by demodulating the data symbol sequence compensated for.

[0018] According to the invention as claimed in claim 5, in the CDMA transceiver as claimed in claim 4, the means for

in the individual pilot blocks.

[0031] According to the invention as claimed in claim 18, a CDMA receiving method which receives a data symbol sequence that is spread, and a pilot symbol sequence that is spread and parallel to the data symbol sequence, and which generates a data sequence by demodulating the spread data symbol sequence by using the spread pilot symbol sequence comprises the steps of:

receiving the spread data symbol sequence and the spread pilot symbol sequence;
generating a data symbol sequence by despreading the spread data symbol sequence;
generating a pilot symbol sequence by despreading the spread pilot symbol sequence;
generating from the pilot symbol sequence a plurality of pilot blocks;
obtaining channel estimates of the data symbols by calculating a weighted sum of averages of the pilot symbols in the individual pilot blocks;
compensating for channel fluctuations in the data symbol sequence by using the channel estimates of the data symbols; and
generating the data sequence by demodulating the data symbol sequence compensated for.

[0032] According to the invention as claimed in claim 19, a CDMA transmitting and receiving method which generates a spread data symbol sequence by modulating a data sequence, transmits the spread data symbol sequence with a pilot symbol sequence which is spread in parallel with the data symbol sequence, receives the spread data symbol sequence and the spread pilot symbol sequence, and generates the data sequence by demodulating the spread data symbol sequence by using the spread pilot symbol sequence, wherein

a transmitting side comprises the steps of:

generating the data symbol sequence by modulating the data sequence;
generating the spread data symbol sequence by spreading the data symbol sequence;
generating the spread pilot symbol sequence by spreading the pilot symbol sequence; and
transmitting the spread data symbol sequence and the spread pilot symbol sequence, and wherein
a receiving side comprises the steps of:
receiving the spread data symbol sequence and the spread pilot symbol sequence;
generating the data symbol sequence by despreading the spread data symbol sequence;
generating the pilot symbol sequence by despreading the spread pilot symbol sequence;
generating from the pilot symbol sequence a plurality of pilot blocks;
obtaining channel estimates of the data symbols by calculating a weighted sum of averages of the pilot symbols contained in the pilot blocks;
compensating for channel fluctuations in the data symbol sequence by using the channel estimates of the data symbols; and
generating the data sequence by demodulating the data symbol sequence compensated for.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033]

Fig. 1 is a block diagram showing a configuration of a channel estimation unit as a first embodiment in accordance with the present invention;
Fig. 2 is a flowchart illustrating a channel estimation processing by the channel estimation unit of the first embodiment in accordance with the present invention;
Fig. 3 is a diagram illustrating, taking an example of the channel estimation, the principle of operation of the channel estimation by the channel estimation unit of the first embodiment in accordance with the present invention;
Fig. 4 is a block diagram showing a configuration of a CDMA receiver as a second embodiment in accordance with the present invention;
Fig. 5 is a flowchart illustrating a receiving processing by the CDMA receiver of the second embodiment in accordance with the present invention;
Fig. 6 is a block diagram showing a configuration of a CDMA transceiver as a third embodiment in accordance with the present invention;
Fig. 7 is a block diagram showing a configuration of a transmitting processor of the CDMA transceiver of the third embodiment in accordance with the present invention;
Fig. 8 is a block diagram showing a configuration of a receiving processor of the CDMA transceiver of the third

$$\tilde{\xi}(n) = \sum_{i=-L,\, i\neq 0}^{L} \alpha(n_i) \cdot \bar{\hat{\xi}}(n_i) \qquad (1)$$

[0044] It is preferable to increase the weights $\alpha(n_i)$ of the pilot blocks that include pilot symbols closer (closer in time) to the nth pilot symbol. This is because such pilot blocks can be considered to represent the state of the propagation path during the transmission of the nth data symbol more correctly because the propagation path fluctuates at every moment.

[0045] The channel estimate acquisition section 120 iterates the foregoing steps S201 - S204 for all the data symbols with which the channel estimates must be obtained (step S205).

[0046] Thus, highly accurate channel estimates can be obtained.

[SECOND EMBODIMENT]

[0047] Fig. 4 is a block diagram showing a configuration of a CDMA receiver as a second embodiment in accordance with the present invention. A CDMA receiver 400 of the present embodiment receives a data symbol sequence which is spread, and a pilot symbol sequence which is spread and parallel to the data symbol sequence, and restores the data sequence by demodulating the spread data symbol sequence using the spread pilot symbol sequence.

[0048] The CDMA receiver 400 comprises a receiving section 410, a data symbol sequence matched filter 424, a pilot symbol sequence matched filter 426, a channel estimation processor 428, a data symbol sequence compensator 430, a RAKE combiner 432, a deinterleaver 434 and a Viterbi decoder 436. Although these components such as the data symbol sequence matched filter 424, pilot symbol sequence matched filter 426 and so forth are implemented in the form of software using a DSP (and a memory that stores programs) 420 as shown in Fig. 4 in the present embodiment, they can be implemented with hardware. The structure and functions of the channel estimation processor 428 are the same as those of the channel estimation unit 100 of the first embodiment in accordance with the present invention.

[0049] Fig. 5 is a flowchart illustrating a receiving processing by the CDMA receiver of the second embodiment in accordance with the present invention. First, at step S501, the receiving section 410 receives the received signal, that is, the spread data symbol sequence and the spread pilot symbol sequence.

[0050] In the present embodiment, it is assumed that the received data symbol sequence and pilot symbol sequence have been spread using a first spreading code and a second spreading code, respectively, which are orthogonal to each other. At step S502, the data symbol sequence matched filter 424 despreads the received signal using the first spreading code, thereby generating the data symbol sequence. At step S503, the pilot symbol sequence matched filter 426 despreads the received signal using the second spreading code, thereby generating the pilot symbol sequence.

[0051] At step S504, the channel estimation processor 428 carries out a channel estimation processing to obtain the channel estimates of the data symbols. The channel estimation processing is the same as that of the channel estimation unit 100 (Fig. 2) of the first embodiment in accordance with the present invention.

[0052] At step S505, the data symbol sequence compensator 430 compensates for the channel fluctuations in the data symbol sequence using the channel estimates $\tilde{\xi}$. More specifically, it compensates for the channel fluctuations in the data symbols by multiplying the data symbol sequence by the complex conjugates of the channel estimates $\tilde{\xi}$.

[0053] At step S506, the RAKE combiner 432, deinterleaver 434 and Viterbi decoder 436 generates the data sequence by demodulating the compensated data symbol sequence. The RAKE combiner 432 carries out the in-phase combining of the compensated data symbol sequence fed from individual RAKE fingers.

[0054] Thus, the receiving processing can achieve highly accurate channel estimation, and the compensation for the channel fluctuations in the data symbol sequence.

[THIRD EMBODIMENT]

[0055] Fig. 6 is a block diagram showing a configuration of a CDMA transceiver as a third embodiment in accordance with the present invention. A CDMA transceiver 600 of the present embodiment comprises a transmitting processor 610 and a receiving processor 620. The transmitting processor 610 generates a spread data symbol sequence by modulating a data sequence, and transmits the spread data symbol sequence along with a pilot symbol sequence which is parallel with the data symbol sequence and undergoes spreading. The receiving processor 620 receives the spread data symbol sequence and the spread pilot symbol sequence, and demodulates the spread data symbol sequence using the spread pilot symbol sequence to generate the data sequence. In the present embodiment, this station (the present CDMA transceiver) exchanges power control symbols with a party station. The power control symbols are symbols

bols are transmitted in a sequence apart from the data symbol sequence and pilot symbol sequence. To transmit the power control symbols in a sequence besides the data symbol sequence and pilot symbol sequence, a means for spreading the power control symbols is provided in the transmitting processor 610. The spread power control symbol sequence is combined with the spread data symbol sequence and the spread pilot symbol sequence to be transmitted. To spread the power control symbol sequence, a third spreading code is used which is orthogonal to the first spreading code used for spreading the data symbol sequence and to the second spreading code used for spreading the pilot symbol sequence. The receiving processor 620 is provided with a means for despreading the power control symbol sequence, and receives the spread power control symbol sequence and despreads it.

[0070] The transmission of the power control symbol sequence can be unidirectional rather than bidirectional. For example, the power control symbol sequence can be transmitted only from a base station to a mobile station to control the (transmission) power of only a reverse channel (from the mobile station to the base station) in communications between the two stations.

[0071] Thus, the transceiver can achieve in its processing highly accurate channel estimation and compensation for the channel fluctuations in the data symbol sequence.

[0072] As described above, the present invention can achieve, when performing the channel estimation of the data symbols, the highly accurate channel estimation by obtaining highly accurate channel estimates by calculating the sum of the pilot symbols which are appropriately weighted.

[0073] In addition, using the pilot symbols in the slots other than the slot including the data symbols to be estimated, the channel estimation of the data symbols can further improve its accuracy.

[0074] The highly accurate channel estimation together with the compensation for the channel fluctuations in the data symbols on the basis of the channel estimation makes it possible to decide the absolute phases of individual data symbols by using the absolute coherent detection, and to reduce the SNIR needed for achieving the desired receiving quality (receiving error rate). As a result, the transmission power can be reduced, and the capacity of the system in terms of the number of subscribers can be increased.

Claims

1. A channel estimation unit for obtaining channel estimates of data symbols from a pilot symbol sequence which is parallel to a data symbol sequence, said channel estimation unit characterized by comprising:

   means for generating a plurality of pilot blocks from the pilot symbol sequence; and
   means for obtaining the channel estimates of the data symbols by calculating a weighted sum of averages of the pilot symbols in the individual pilot blocks.

2. A CDMA receiver which receives a data symbol sequence that is spread, and a pilot symbol sequence that is spread and parallel to the data symbol sequence, and which generates a data sequence by demodulating the spread data symbol sequence by using the spread pilot symbol sequence, said CDMA receiver characterized by comprising:

   means for receiving the spread data symbol sequence and the spread pilot symbol sequence;
   means for generating a data symbol sequence by despreading the spread data symbol sequence;
   means for generating a pilot symbol sequence by despreading the spread pilot symbol sequence;
   means for generating from the pilot symbol sequence a plurality of pilot blocks;
   means for obtaining channel estimates of the data symbols by calculating a weighted sum of averages of the pilot symbols in the individual pilot blocks;
   means for compensating for channel fluctuations in the data symbol sequence by using the channel estimates of the data symbols; and
   means for generating the data sequence by demodulating the data symbol sequence compensated for.

3. The CDMA receiver as claimed in claim 2, characterized in that the spread data symbol sequence has been spread using a first spreading code, the spread pilot symbol sequence has been spread using a second spreading code, said means for generating the data symbol sequence despreads the spread data symbol sequence which has been spread using the first spreading code, and said means for generating the pilot symbol sequence despreads the spread pilot symbol sequence which has been spread using the second spreading code, and characterized in that the first spreading code and the second spreading code are orthogonal to each other.

4. A CDMA transceiver having a transmitting processor and a receiving processor, said transmitting processor generating a spread data symbol sequence by modulating a data sequence, and transmitting the spread data symbol

12. The CDMA transceiver as claimed in any one of claims 4-11, characterized in that said receiving processor further comprises means for generating the power control symbol sequence by despreading the spread power control symbol sequence for controlling the power of the data symbol sequence and that of the pilot symbol sequence; and means for extracting the power control symbol sequence, and characterized in that said means for receiving the spread data symbol sequence and the spread pilot symbol sequence receives the spread power control symbol sequence, and said means for transmitting the spread data symbol sequence and the spread pilot symbol sequence transmits the spread data symbol sequence and the spread pilot symbol sequence in accordance with the power control symbol sequence.

13. The equipment as claimed in any one of claims 1-12, characterized in that the power of the data symbol sequence and that of the pilot symbol sequence are controlled on a slot by slot basis, and characterized in that the plurality of pilot blocks each consist of pilot symbols belonging to at least two different slots.

14. The equipment as claimed in any one of claims 1-13, characterized in that when obtaining the channel estimate of an nth data symbol in the data symbol sequence, where n is an integer, the plurality of the pilot blocks each consist of pilot symbols from (n-K+1)th pilot symbol to (n+K)th pilot symbol in the pilot symbol sequence, where K is a natural number.

15. The equipment as claimed in any one of claims 1-14, characterized in that the plurality of pilot blocks have a same length, each.

16. The equipment as claimed in any one of claims 1-15, characterized in that when obtaining the channel estimate of an nth data symbol in the data symbol sequence, where n is an integer, the pilot blocks consisting of pilot symbols closer to the nth pilot symbol have a greater weight.

17. A channel estimation method for obtaining channel estimates of data symbols from a pilot symbol sequence which is parallel with a data symbol sequence, said channel estimation method characterized by comprising the steps of:

   generating a plurality of pilot blocks from the pilot symbol sequence; and
   obtaining the channel estimates of the data symbols by calculating a weighted sum of averages of the pilot symbols in the individual pilot blocks.

18. A CDMA receiving method which receives a data symbol sequence that is spread, and a pilot symbol sequence that is spread and parallel to the data symbol sequence, and which generates a data sequence by demodulating the spread data symbol sequence by using the spread pilot symbol sequence, said CDMA receiving method characterized by comprising the steps of:

   receiving the spread data symbol sequence and the spread pilot symbol sequence;
   generating a data symbol sequence by despreading the spread data symbol sequence;
   generating a pilot symbol sequence by despreading the spread pilot symbol sequence;
   generating from the pilot symbol sequence a plurality of pilot blocks;
   obtaining channel estimates of the data symbols by calculating a weighted sum of averages of the pilot symbols in the individual pilot blocks;
   compensating for channel fluctuations in the data symbol sequence by using the channel estimates of the data symbols; and
   generating the data sequence by demodulating the data symbol sequence compensated for.

19. A CDMA transmitting and receiving method which generates a spread data symbol sequence by modulating a data sequence, transmits the spread data symbol sequence with a pilot symbol sequence which is spread in parallel with the data symbol sequence, receives the spread data symbol sequence and the spread pilot symbol sequence, and generates the data sequence by demodulating the spread data symbol sequence by using the spread pilot symbol sequence, wherein
a transmitting side comprises the steps of:

   generating the data symbol sequence by modulating the data sequence;
   generating the spread data symbol sequence by spreading the data symbol sequence;
   generating the spread pilot symbol sequence by spreading the pilot symbol sequence; and
   transmitting the spread data symbol sequence and the spread pilot symbol sequence, and wherein

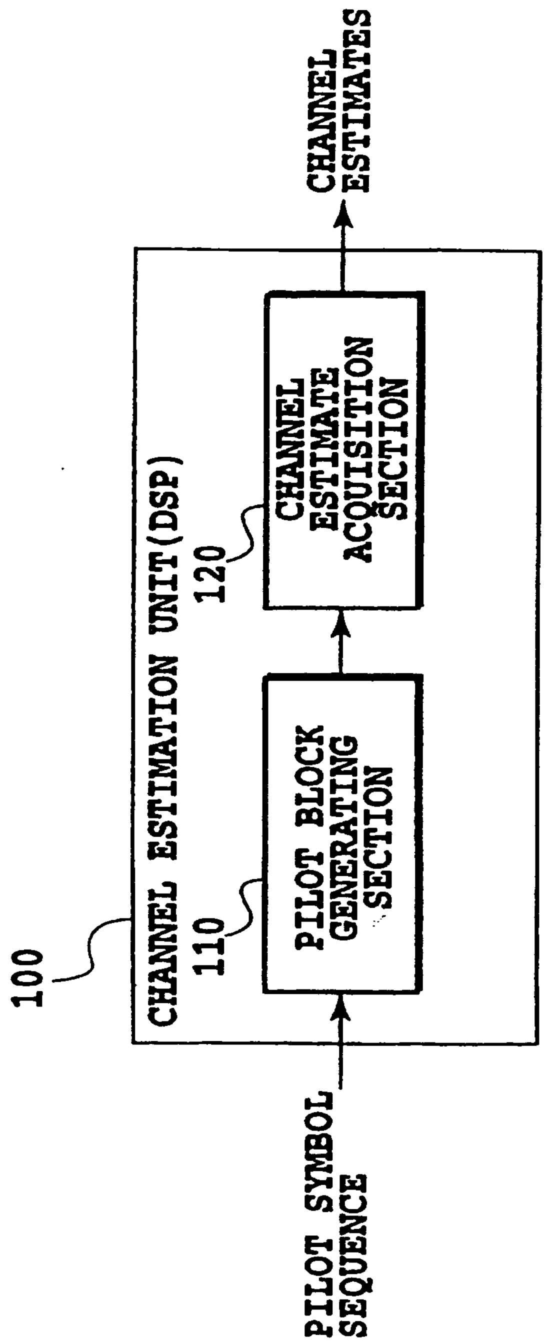

100
CHANNEL ESTIMATION UNIT(DSP)
110
PILOT BLOCK GENERATING SECTION
120
CHANNEL ESTIMATE ACQUISITION SECTION
PILOT SYMBOL SEQUENCE
CHANNEL ESTIMATES

FIG.1

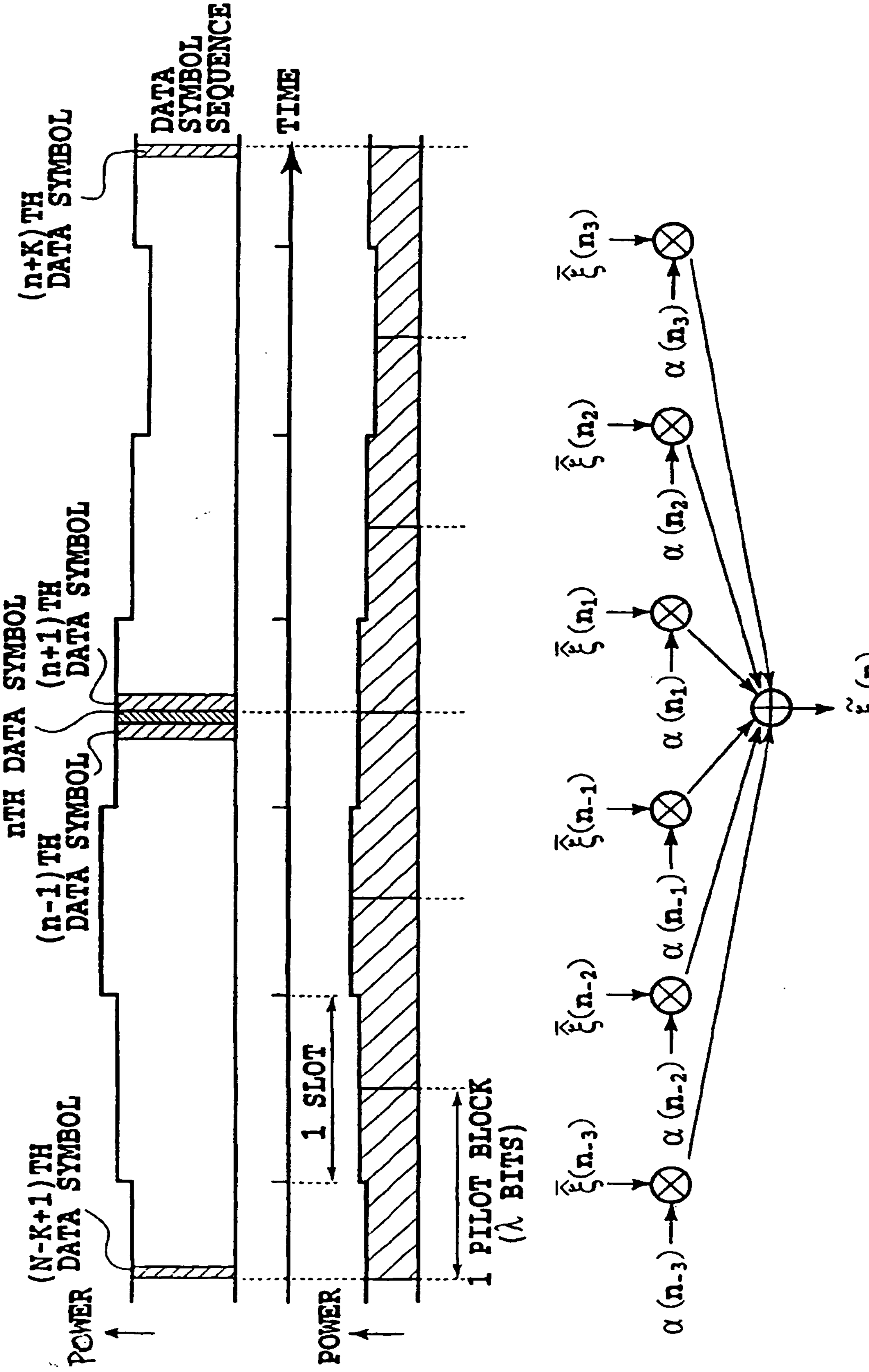

POWER
(N-K+1)TH DATA SYMBOL
(n-1)TH DATA SYMBOL
nTH DATA SYMBOL
(n+1)TH DATA SYMBOL
(n+K)TH DATA SYMBOL
DATA SYMBOL SEQUENCE
TIME
1 SLOT
POWER
1 PILOT BLOCK (λ BITS)
$\hat{\xi}(n_{-3})$
$\hat{\xi}(n_{-2})$
$\hat{\xi}(n_{-1})$
$\hat{\xi}(n_1)$
$\hat{\xi}(n_2)$
$\hat{\xi}(n_3)$
$\alpha(n_{-3})$
$\alpha(n_{-2})$
$\alpha(n_{-1})$
$\alpha(n_1)$
$\alpha(n_2)$
$\alpha(n_3)$
$\tilde{\xi}(n)$
CHANNEL ESTIMATE OF nTH DATA SYMBOL

FIG.3

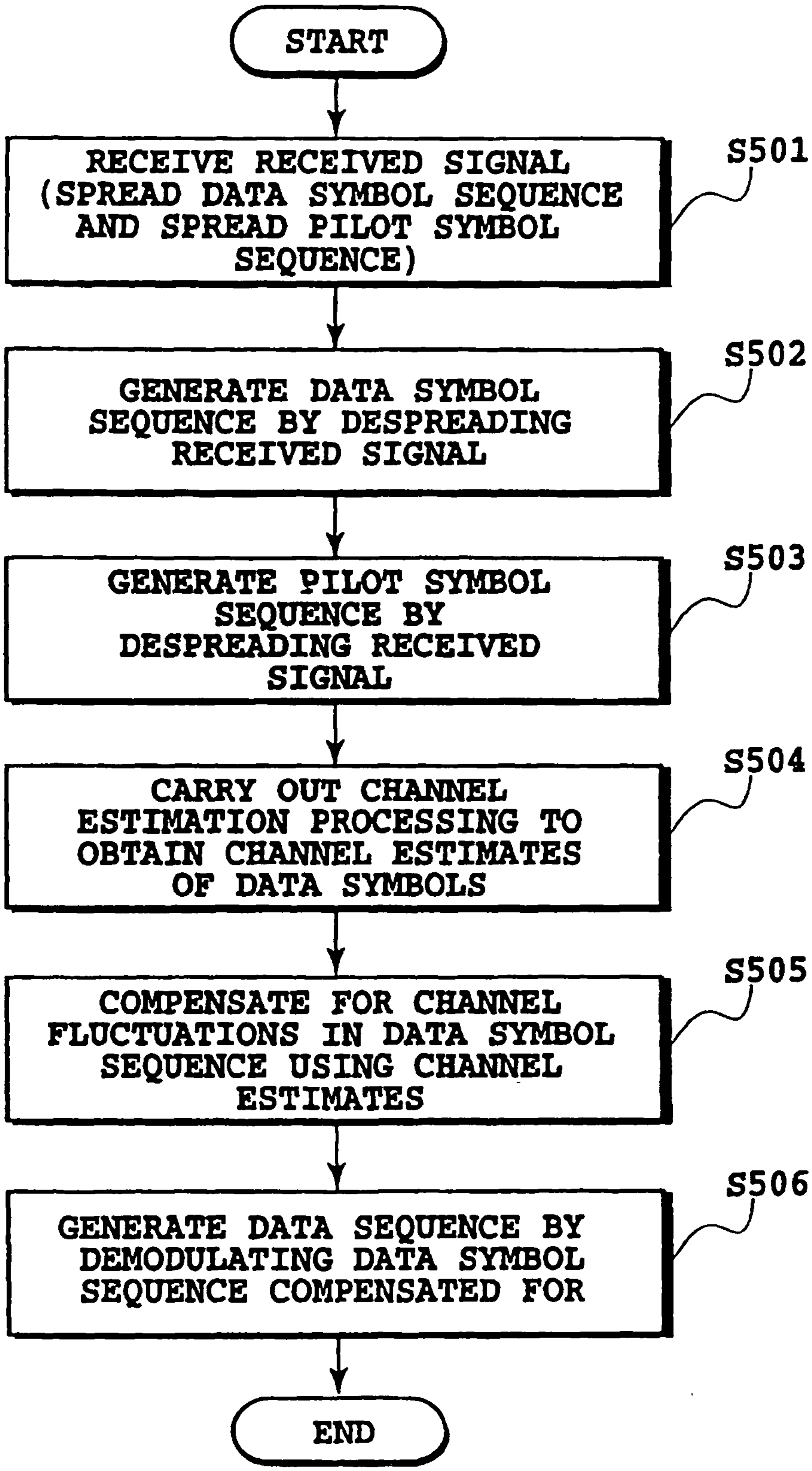

START
RECEIVE RECEIVED SIGNAL (SPREAD DATA SYMBOL SEQUENCE AND SPREAD PILOT SYMBOL SEQUENCE)
S501
GENERATE DATA SYMBOL SEQUENCE BY DESPREADING RECEIVED SIGNAL
S502
GENERATE PILOT SYMBOL SEQUENCE BY DESPREADING RECEIVED SIGNAL
S503
CARRY OUT CHANNEL ESTIMATION PROCESSING TO OBTAIN CHANNEL ESTIMATES OF DATA SYMBOLS
S504
COMPENSATE FOR CHANNEL FLUCTUATIONS IN DATA SYMBOL SEQUENCE USING CHANNEL ESTIMATES
S505
GENERATE DATA SEQUENCE BY DEMODULATING DATA SYMBOL SEQUENCE COMPENSATED FOR
S506
END

FIG.5

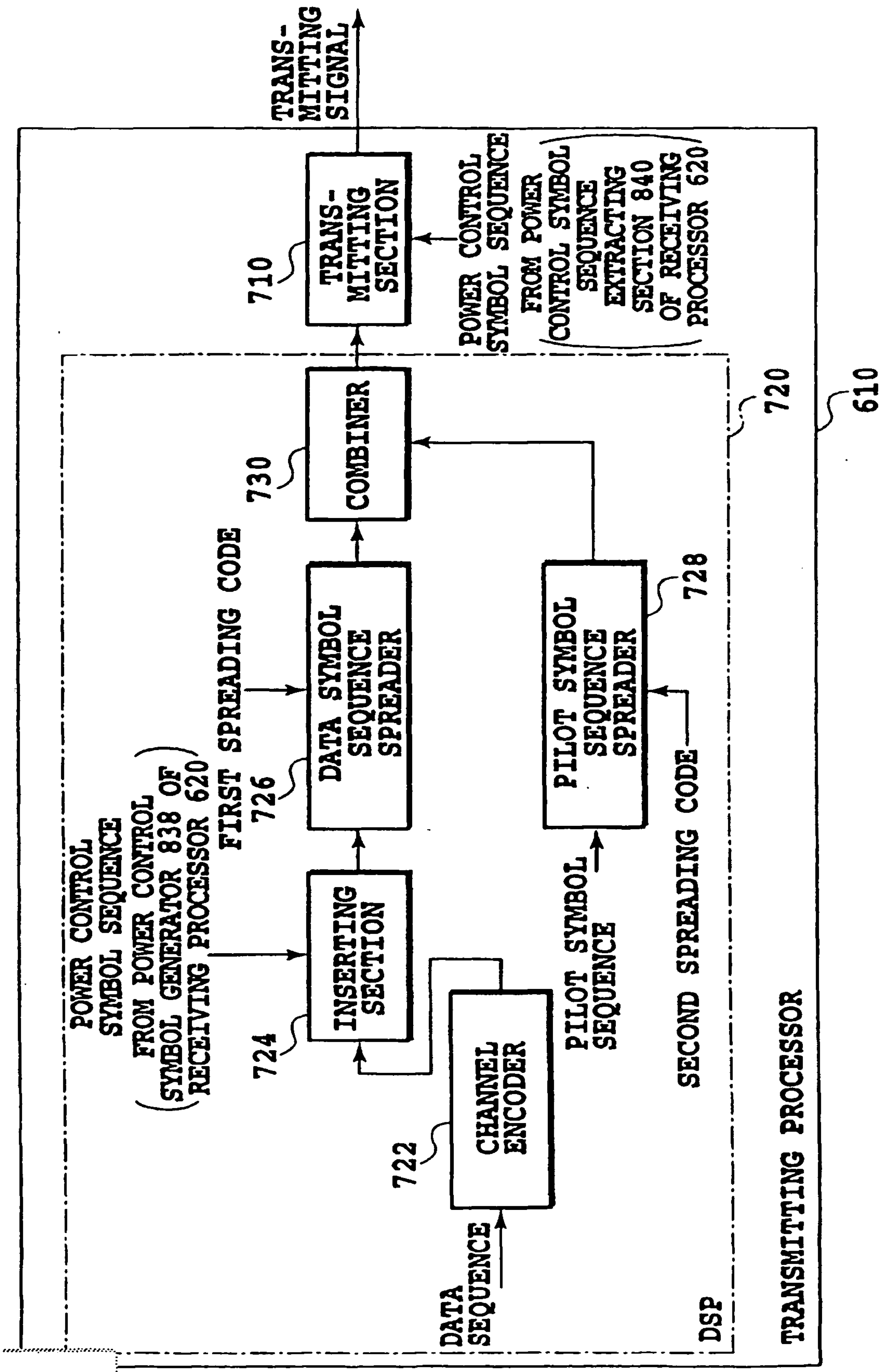

TRANS-
MITTING
SIGNAL
710
TRANS-
MITTING
SECTION
POWER CONTROL
SYMBOL SEQUENCE
(FROM POWER
CONTROL SYMBOL
SEQUENCE
EXTRACTING
SECTION 840
OF RECEIVING
PROCESSOR 620)
730
COMBINER
720
610
FIRST SPREADING CODE
726
DATA SYMBOL
SEQUENCE
SPREADER
728
PILOT SYMBOL
SEQUENCE
SPREADER
SECOND SPREADING CODE
PILOT SYMBOL
SEQUENCE
POWER CONTROL
SYMBOL SEQUENCE
(FROM POWER CONTROL
SYMBOL GENERATOR 838 OF
RECEIVING PROCESSOR 620)
724
INSERTING
SECTION
722
CHANNEL
ENCODER
DATA
SEQUENCE
DSP
TRANSMITTING PROCESSOR

FIG.7

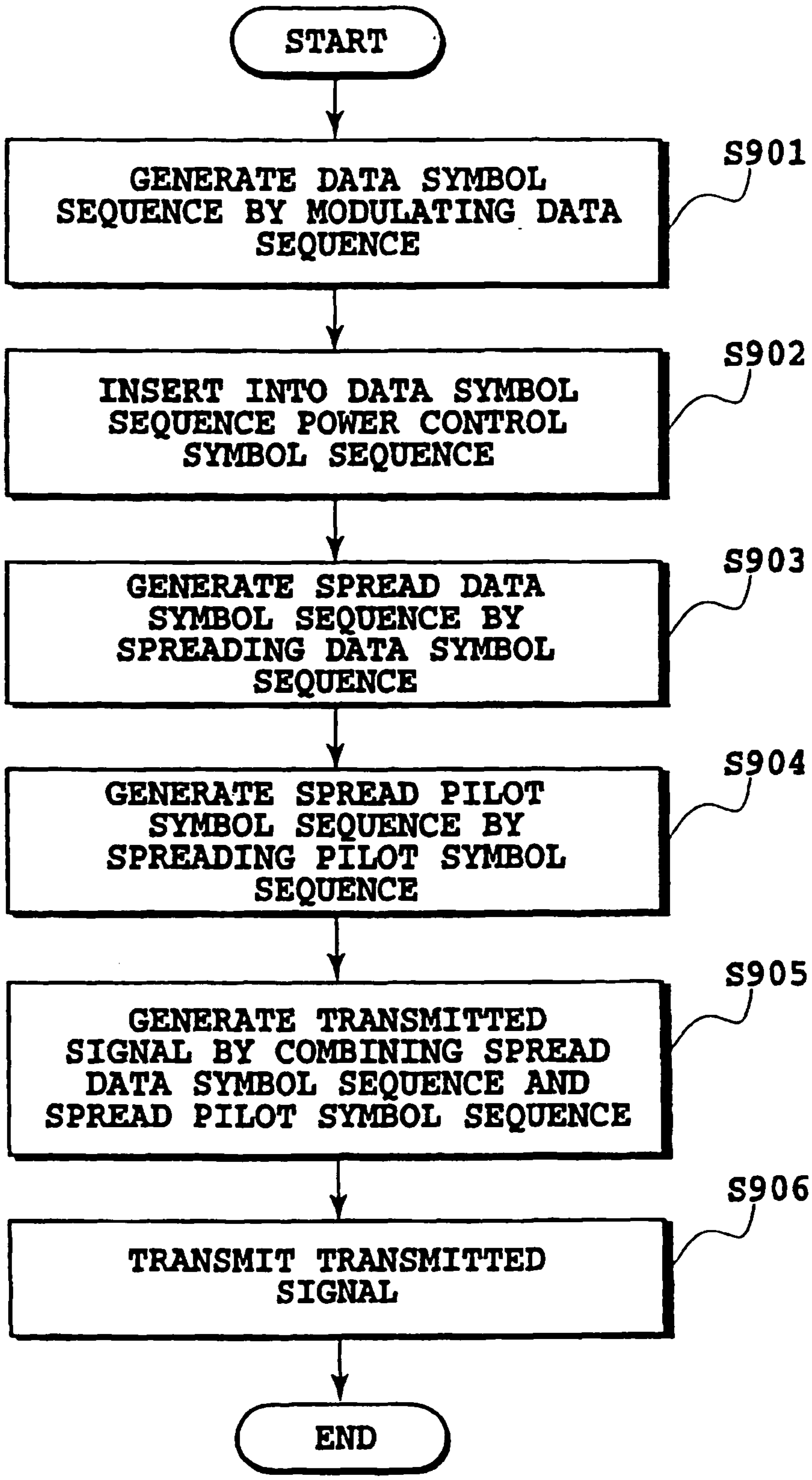

START
GENERATE DATA SYMBOL SEQUENCE BY MODULATING DATA SEQUENCE
S901
INSERT INTO DATA SYMBOL SEQUENCE POWER CONTROL SYMBOL SEQUENCE
S902
GENERATE SPREAD DATA SYMBOL SEQUENCE BY SPREADING DATA SYMBOL SEQUENCE
S903
GENERATE SPREAD PILOT SYMBOL SEQUENCE BY SPREADING PILOT SYMBOL SEQUENCE
S904
GENERATE TRANSMITTED SIGNAL BY COMBINING SPREAD DATA SYMBOL SEQUENCE AND SPREAD PILOT SYMBOL SEQUENCE
S905
TRANSMIT TRANSMITTED SIGNAL
S906
END

FIG.9

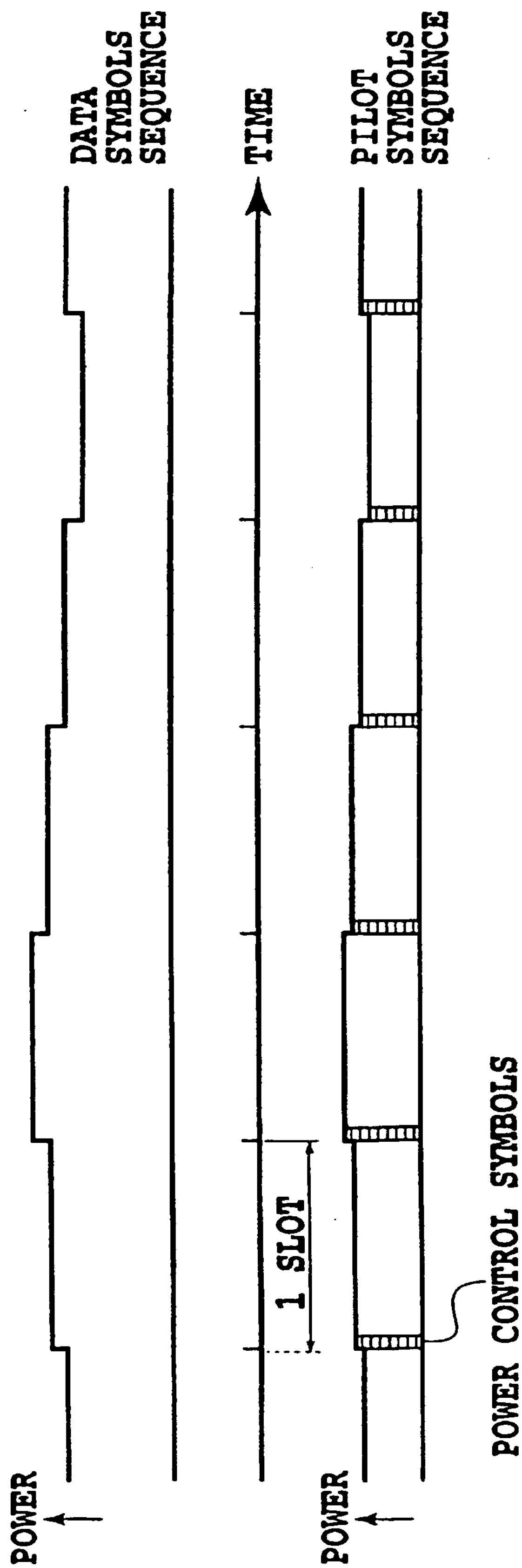

DATA SYMBOLS SEQUENCE
TIME
PILOT SYMBOLS SEQUENCE
1 SLOT
POWER CONTROL SYMBOLS
POWER
POWER

FIG.11

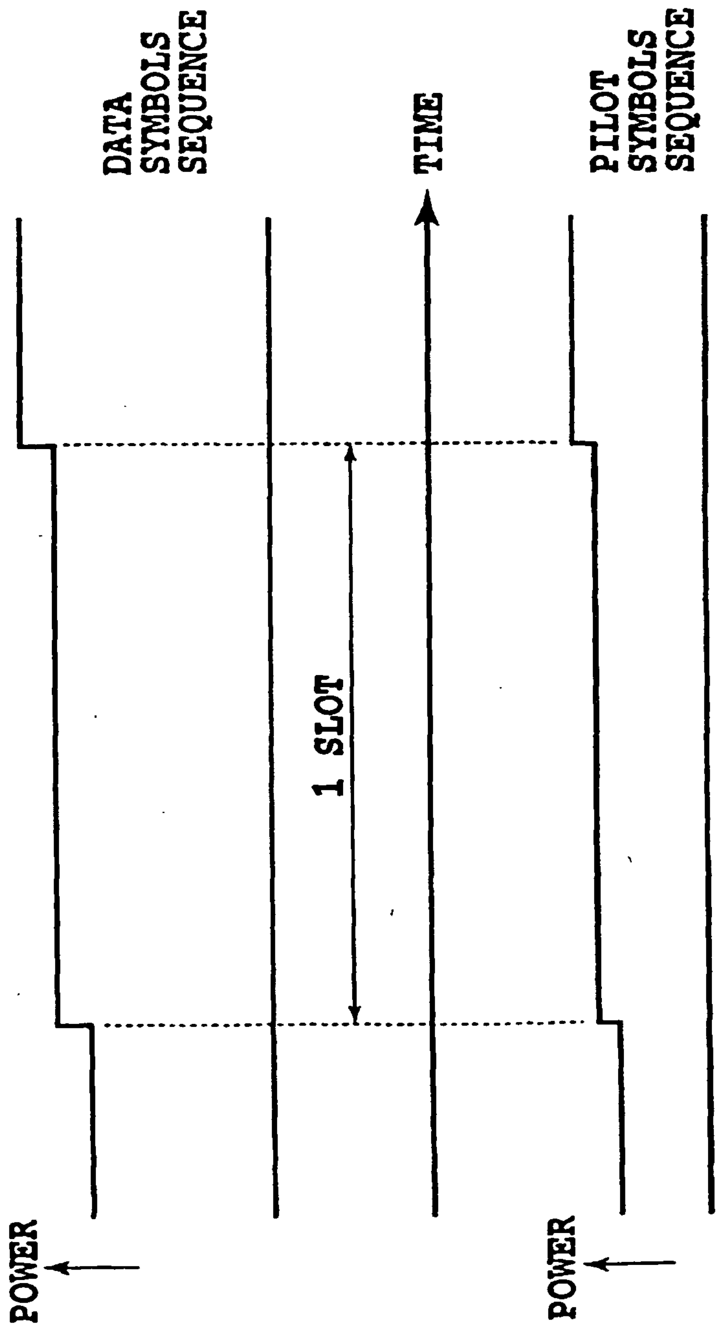

POWER
DATA SYMBOLS SEQUENCE
1 SLOT
TIME
POWER
PILOT SYMBOLS SEQUENCE

FIG.13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP98/05241

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, 8-88589, A (Hitachi,Ltd.), 2 April, 1996 (02. 04. 96), Par. No. [0036] ; Fig. 1 & EP, A2, 693830 & CA, A, 2153516 & US, A, 5666352 & CN, A, 1118976	3, 5

Form PCT/ISA/210 (continuation of second sheet) (July 1992)